CNTT-E-119

# BASIC ELECTRICITY AND ELECTRONICS

# STUDENT HANDOUT

# NO. 212

## SUMMARIES
## PROGRESS CHECKS
FOR
## MODULES

## 25 LESSONS 1&2

JUNE 1984

# SUMMARY
# LESSON 1

## Silicon Controlled Rectifier Theory

The Silicon Controlled Rectifier is a solid state device used in motor controllers, switching circuits and power supply circuits. Its advantages include the following:

It is quiet in operation.
Vibration and shock do not affect it.
Most important, you can control a large amount of voltage and current with a small controlling voltage.

We can see from the schematic symbol shown below that the SCR has 3 leads.

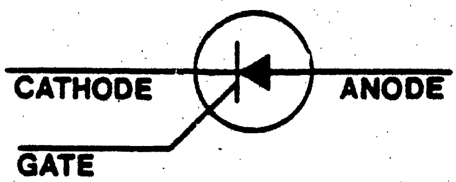



Figure 1

The anode and cathode leads are the same as the diode you have studied previously. The gate lead is added to control conduction of the SCR.

Like a diode, the SCR must be forward biased to conduct - - negative on the cathode, positive on the anode.

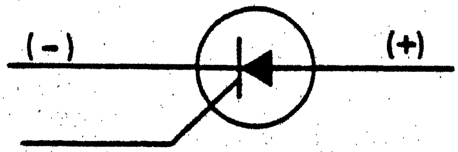



Figure 2

Unlike a diode, the SCR must have a positive signal on the gate lead (usually +.1 to +1 v) while it is forward biased or it will not conduct.

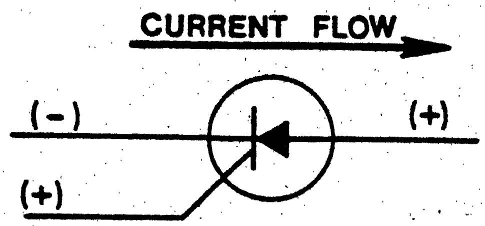
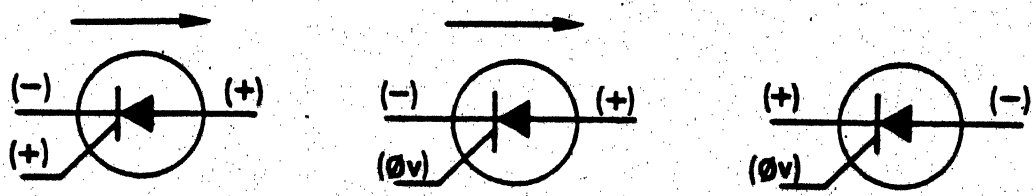



Figure 3

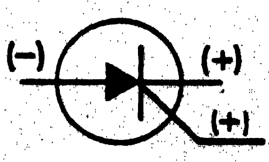
In Figure 3, the conditions for conduction are met. Current flows from cathode to anode. If we remove the gate signal, the SCR will remain in conduction; however, if we remove forward bias, the SCR will cut off. (Stop conducting.)




SCR Conducting SCR Conducting SCR Cut Off

Figure 4

If we reverse bias the SCR, then it will not conduct even if we apply a positive gate signal.




SCR Cut Off
Figure 5

Using this information let's look at an SCR with a DC voltage applied.

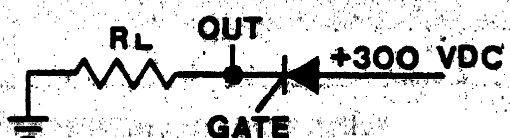



Figure 6

The output waveform will be taken across R

This SCR needs +.1v on the gate to conduct.

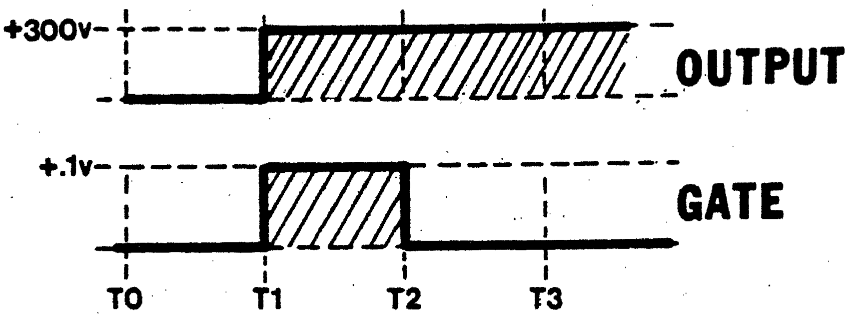



Figure 7

At T0 there is no output although forward bias is applied. When the gate voltage is applied at T1 the SCR conducts and we will see the +300 VDC across $R_L$. Even though we remove the gate voltage at T2 the SCR remains in conduction as long as forward bias is applied. If we remove the forward bias then the SCR will stop conducting.

Let's examine an SCR with AC applied to the anode and a DC voltage applied to the gate.

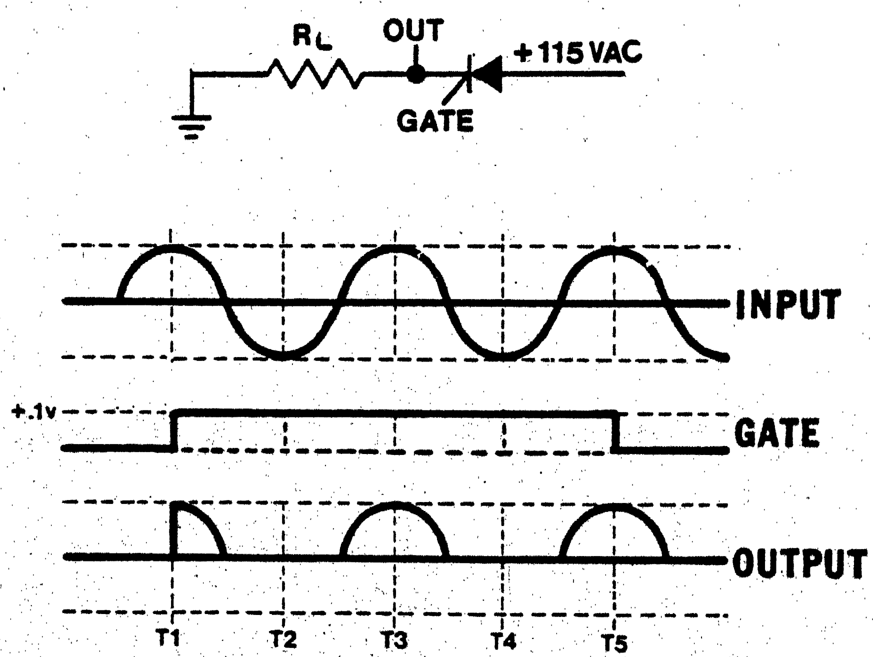



Figure 8

As you can see, the SCR will conduct only when it is forward biased and has the proper gate signal. With AC applied to the input and to the gate we can choose a variety of waveforms by varying the gate signal.

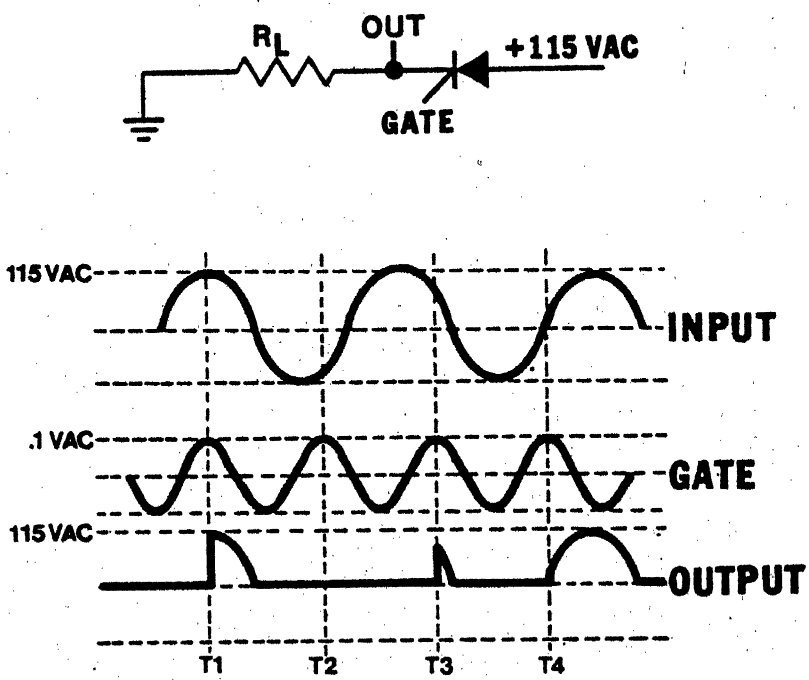



Figure 9

Notice that the SCR conducts only when the proper gate signal coincides with the proper forward bias. By timing the gate signal we can make the SCR pass the entire positive portion of the waveform or only part of it.

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JOB PROGRAM
FOR
LESSON I
PART I

## Silicon Controlled Rectifier DC Control

### EQUIPMENT AND MATERIALS

1. Training Device 6F16, Template "J"

### PROCEDURE

1. Set up Device 6F16 using Template J and the parts called for by the template. Observe all applicable safety precautions.

NOTE: Do not install jumper "F". Do not energize the device.

2. When this circuit is energized, will DS1 light?

3. Now energize the 6F16 using the line cord.

4. Why is the light out at this time?

   a. The SCR is forward biased.
   b. The SCR is reverse biased.
   c. There is no gate voltage applied.
   d. There is a positive gate voltage applied.

5. What will happen if jumper "F" is installed?

   a. The SCR will cut off.
   b. The SCR will conduct.
   c. The light will remain off.

6. Install Jumper "F".

7. What did jumper "F" do to the circuit?

   a. Forward biased the SCR.
   b. Reverse biased the SCR.
   c. Applied a negative voltage to the gate lead.
   d. Applied a positive voltage to the gate lead.

8. If jumper "F" is removed, will the light go out?

9. Remove jumper "F".

10. Now that the SCR is conducting, how can the circuit be restored to it's "off" condition?

a. Apply a positive voltage to the gate.
b. Remove the gate voltage.
c. Remove shorting straps.
d. Apply a ground to the gate lead.

11. Test your answer to #10 by momentarily performing the action you chose.

NOTE: If you chose answer "A" obtain the voltage from the bottom of resistor R2. DO NOT apply full positive voltage to the gate lead. The SCR may be damaged if a high voltage is applied to the gate.

12. If the light goes off and remains off when the circuit is restored, your answer to #10 is correct. If the light is still lit, go back to #10 and try again.

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JOB PROGRAM
FOR
LESSON I
PART 2

Silicon Controlled Rectifier AC Control

EQUIPMENT AND MATERIALS

1. Oscilloscope
2. 1X Probe (2 required)
3. Device 6F16 with Template "K" - Silicon Control Rectifier AC Control Characteristics.

PROCEDURE

1. Using all applicable safety precautions, energize the oscilloscope and obtain a line trace. Make the following settings:

   a. TRIGGER SOURCE to "LINE"
   b. TIME/DIV to 5 millisec/div
   c. DISPLAY MODE to "CHOP"
   d. VOLTS/DIV to 10 volts/div (Channel "1") and 5 volts/div (Channel "2")
   e. SWEEP POSITION Channel "1" to +1 div; Channel "2" to -1 div.

II. Using all applicable safety precautions, set up Device 6F16 using Template #K and the parts called for on the template. Energize the 6F16 using the line cord.

III.1. Using the X1 probes, connect channel "1" of the oscilloscope to the AC input to the circuit. (Left side of DS1). Connect channel "2" to the top of R4.

2. Turn Potentiometer R2 fully clockwise (as viewed from the knob side).

NOTE: This gates the SCR on at the same time as the anode goes positive.

3. Channel "2" is displaying (full wave; half wave; no) rectification.

4. The SCR is operating like a (transistor; resistor; diode.)

5. Perform the following steps:

   a. Remove the channel "1" probe from the input and reconnect it to the anode of CR1.
   b. Turn R2 fully counter-clockwise.
   c. Set DISPLAY MODE to "2".
   d. Set "2" VOLTS/DIV to 2 volts/div.
   e. Slowly turn R2 clockwise until positive pulses just appear on the trace.

f. Set POS ◄► until the leading edge of the middle pulse coincides with the vertical center line of the graticule. The leading edge of the pulse is the "turn on" time of the SCR.

g. Set DISPLAY MODE to "1".

h. Set "1" VOLTS/DIV to 2 volts/div.

i. Using channel "1" POSITION set the positive peaks of the sine wave at the horizontal center line of the graticule. The horizontal center line of the graticle now represents the "turn on" voltage for the SCR. This is a representation of the voltage applied to the gate lead of the SCR.

j. Set the DISPLAY MODE to "CHOP." The sweeps will be superimposed, so remember which waveform is the input and which is the output.

6. What happens to the SCR when the voltage to the gate reaches the horizontal centerline of the graticule? The SCR (cuts off/conducts).

7. Turn R2 clockwise until the peak voltage displayed on channel "1" reaches +.2 cm. (One small division above horizontal centerline.)

8. The gate voltage now reaches "turn on" voltage (earlier/later/at the same time) in the applied sine wave.

9. The SCR is now conducting (more/less/the same).

10. Turn R2 clockwise until the peak voltage to the gate is at +.6 cm (three small divisions above the centerline). What happened to the conduction time of the SCR? The conduction time (increased/decreased/remained the same).

11. Which of the statements below best describes the action of the SCR in this circuit?

    a. SCR conduction begins at the time the gate signal reaches the "Turn on" voltage level.

    b. SCR conduction increases when the gate voltage increases.

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# PROGRESS CHECK
## LESSON 1

## Silicon Control Rectifier Theory

1. SCR's are not affected by

   a. heat.
   b. vibration.
   c. cold.
   d. current.

2. The SCR is similar to a ______________________________

3. The three leads of an SCR are the ______________, the ______________, and the ____________________.

4. The bias conditions necessary to <u>start</u> an SCR into conduction are

   a. positive on the anode, negative on the cathode.
   b. negative on the anode, positive on the cathode.
   c. positive on the anode, negative on the cathode, and positive on the gate.
   d. negative on the anode, positive on the cahode, and negative on the gate.

5. The bias conditions necessary to <u>maintain</u> an SCR in conduction are

   a. positive on the anode, negative on the cathode.
   b. negative on the anode, positive on the cathode.
   c. negative on the anode, positive on the cathode, and positive on the gate.
   d, positive on the anode, positive on the cathode, and positive on the gate.

6. The direction of current flow through a conducting SCR is

   a. cathode to anode.
   b. anode to cathode.
   c. gate to anode.
   d. cathode to gate.

7. One way to stop conduction of an SCR is to

   a. remove the gate signal.
   b. reverse bias the SCR.
   c. increase forward bias.
   d. ground the cathode.

8. The output of an SCR with an "AC" input on the anode and a "DC" gate signal will look like

a. 

b. 

c. 

d. 

9. The shape of the output waveform of an SCR with an AC input and an AC gate signal depends upon

a. gate timing/gate signal amplitude
b. input amplitude/gate timing
c. gate signal amplitude/the type of SCR
d. the type of SCR/input amplitude

10. The "turn on" voltage required on the gate lead of most SCR's ranges between

a. +1 to +10 volts.
b. +5 to +50 volts.
c. -3 to +3 volts.
d. +.1 to +1 volts.

11. Power output <u>control</u> of an SCR with an AC input signal is accomplished by

a. applying and removing forward bias to the anode and cathode.
b. applying and removing reverse bias to the anode and cathode.
c. increasing and decreasing the AC amplitude applied to the gate below the triggering level.
d. increasing and decreasing the AC amplitude applied to the gate.

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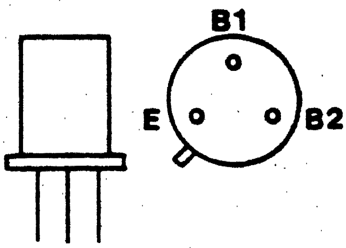
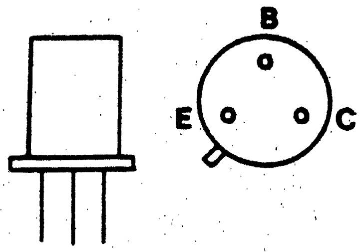
SUMMARY
LESSON II

## Unijunction Transistor Theory

The Unijunction Transistor is a solid state device used in switching and timing circuits. Its physical appearance is identical to a common transistor.

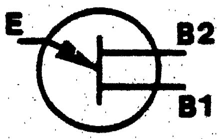



UJT



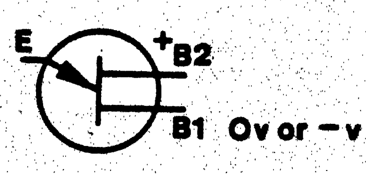

TRANSISTOR

A second base lead instead of a collector is the major difference between a UJT and a transistor. The schematic symbol for a UJT looks like this:

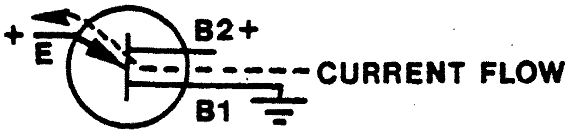



The lead with the arrow is the emitter; Base 1 (B1) is the lead to which the emitter arrow points; the Base 2 (B2) is the other lead. Base 2 can be compared to the collector of a common transistor in that Base 2 is usually where Vcc is applied.

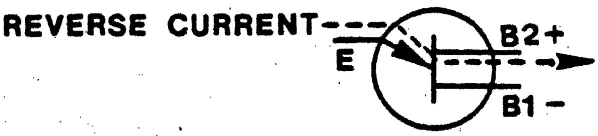
Proper operation of a UJT depends upon proper bias. The UJT must have a positive voltage level on Base 2 and a less positive voltage level on Base 1.



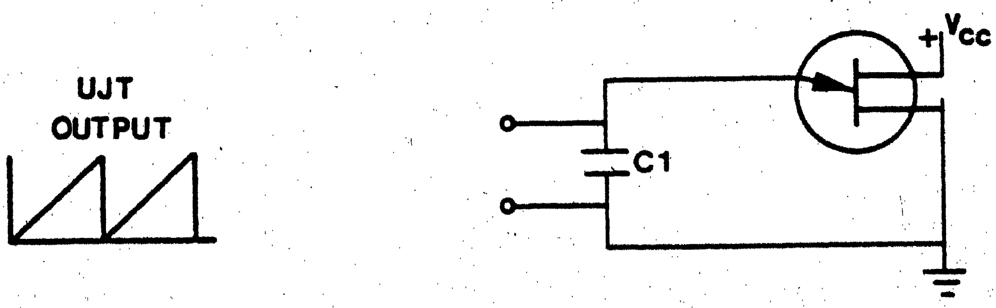
This type of voltage arrangement prepares the UJT for conduction. When a positive voltage level large enough to forward bias the E-B1 junction appears on the emitter the UJT conducts. Current flow is from B1 to the emitter -- against the arrow.



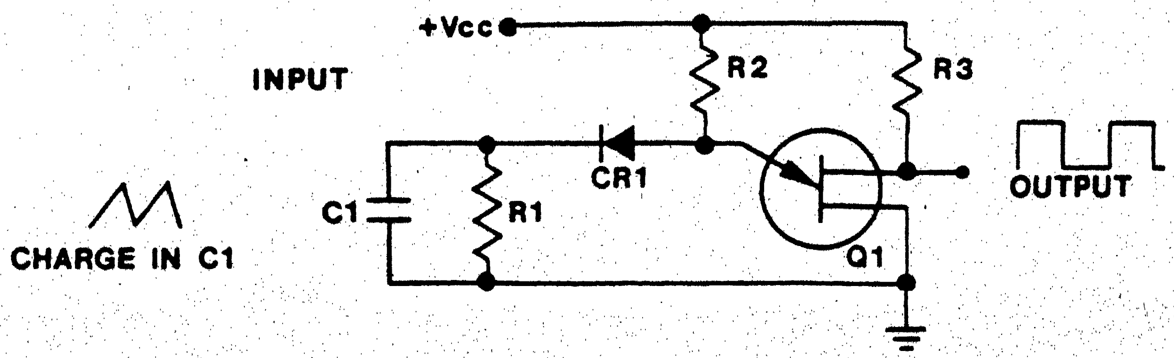

If there is no voltage on the emitter or if the voltage level is too low then the E-B1 junction is reverse biased and no current flows through the E-B1 junction. However; a small reverse current flows from the emitter to B2 due to imperfections in the material.



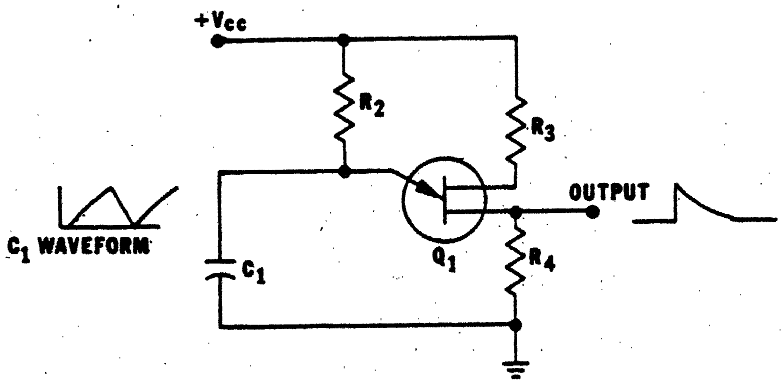

A UJT sawtooth generator produces a sawtooth waveform output due to the charge and discharge of C1 and the switching action of the UJT.




In the UJT multivibrator the combined switching action of CR1 and the UJT controls the charge and discharge of C1 and develops a square wave output at B2 of Q1.



A trigger circuit may be constructed by removing CR1 and R1 from the multivibrator circuit and placing a resistor between B1 and ground. The output is taken from B1 of the UJT. The schematic diagram of a typical UJT trigger circuit is:

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JOB PROGRAM
FOR
LESSON II
PART I

## Unijunction Transistor Sawtooth/Trigger Generator

### EQUIPMENT AND MATERIALS

1. Device 6F16 and Template L
2. Oscilloscope
3. 1X Probe (2)

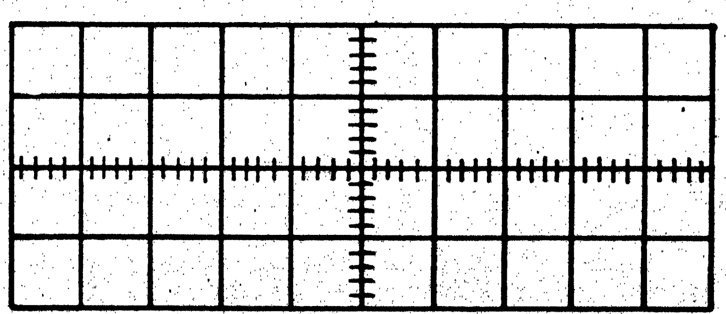
### PROCEDURES

1. Energize oscilloscope, and obtain a dual line trace. Make the following settings:

   a. DISPLAY MODE - CHOP
   b. TIME/DIV - 1 MILLISEC/DIV
   c. VOLTS/DIV - Channel 1 - .5 VOLTS/DIV
      Channel 2 - 2 VOLTS/DIV
   d. Set Channel 1 line trace +1 division above horizontal axis.
   e. Set Channel 2 line trace -1 division below horizontal axis.

2. Using all applicable safety precautions, set up 6F16, using Template L and the required parts. Energize the 6F16 using AC line cord.

3. Connect a 1X probe from Channel 1 input on the oscilloscope to the emitter of Q1 ("D"). Observe and draw the waveform on Channel 1.



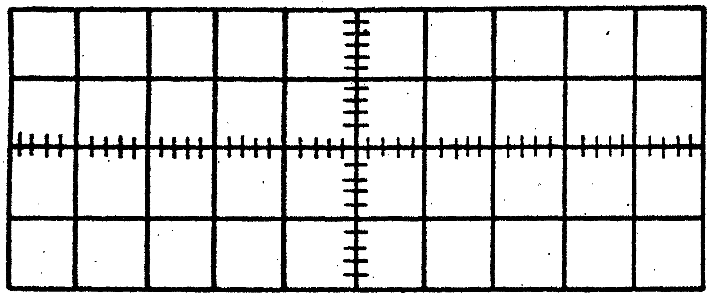
4. a. Channel 1 is displaying a (sine, square, trigger, or sawtooth waveform).

______________________________________________________________.

   b. How much peak-to-peak voltage do you read? ____________ V p-p.

   c. Indicate on the waveform you drew the point at which the UJT starts to conduct.

5. Connect a 1X probe from Channel 2 input on the oscilloscope to Base 1 of Q1 ("C"). Observe and draw the waveforms. Change TIME/DIV to 2 MILLISEC/DIV.



6. a. Channel 2 is displaying a (sine, square, trigger, or sawtooth waveform). ______________________________.

b. How much peak to peak voltage do you read? ______________V p-p.

c. The UJT is at its highest conduction when the waveform at Base 1 is (not present, most positive, or least positive). ______________.

7. a. From this Job Program you can see that you get two very different types of waveforms at different points on the UJT. By connecting the oscilloscope input to the emitter, you see a (sine, square, trigger, or sawtooth) waveform output. ______________________.

b. By connecting the oscilloscope to Base 1, a (sine, square, trigger, or sawtooth) waveform is seen. ______________________.

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# JOB PROGRAM
# FOR
# LESSON II
# PART II

## Unijunction Transistor Multivibrator

## EQUIPMENT AND MATERIALS

1. Device 6F16 and Template M
2. Oscilloscope
3. 1X Probe (2)

## PROCEDURES

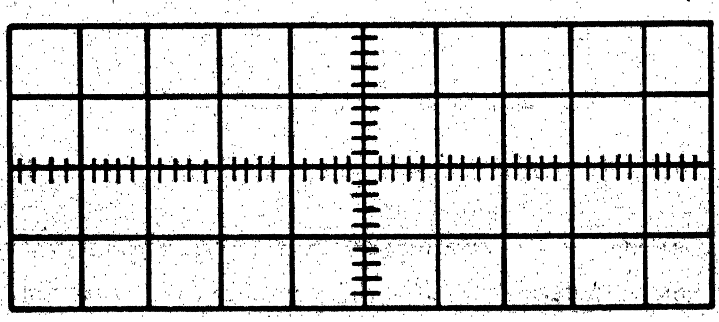
1. Energize the oscilloscope and obtain a dual line trace. Make the following settings:

    a. DISPLAY MODE - CHOP
    b. TIME/DIV - 5 MILLISEC/DIV
    c. VOLTS/DIV - AS REQUIRED
    d. Set Channel 1 line trace +1 division above horizontal axis.
    Set Channel 2 line trace -1 division below horizontal axis.

2. Using all applicable safety precautions, set up training device 6F16 using Template M and the required parts. Energize the 6F16 using the AC line cord.

3. Connect a 1X probe from the oscilloscope channel 1 input to Base 2 ("F") of Q1.

    a. Observe and draw the waveform appearing on Channel 1 of the oscilloscope.



    b. Channel 1 is displaying a (sine, square, trigger, or sawtooth) waveform.

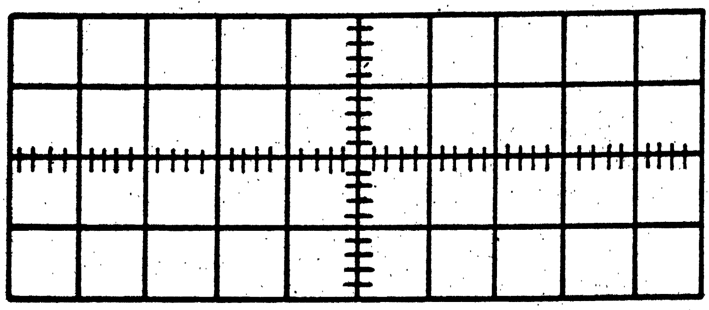
    ______________________________.

    c. How much peak-to-peak voltage do you read? __________ V p-p.

4. Connect another 1X probe from Channel 2 input on the oscilloscope to the cathode of CR1.

4. (continued)

a. Observe and draw the waveform shown on Channel 2.



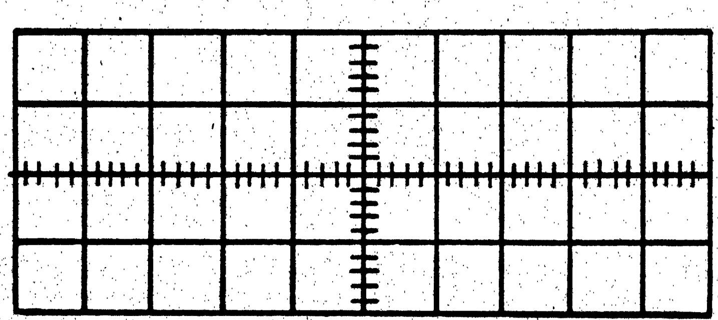
b. The waveform displayed on Channel 2 of the oscilloscope is a (sine, square, trigger, or sawtooth) waveform. ______________________.

c. How much peak-to-peak voltage do you read? ________________V p-p.

d. Q1 begins to conduct at ______________________________volts.

5. Connect the Channel 2 1X probe to the anode of CR1.

a. Observe and draw the waveform on Channel 2.



b. Is the waveform different than the waveform on the cathode? __________.

c. Why? ______________________________________________.

6. What is the relationship of the conduction and cutoff times of Q1 and CR1?

a. Q1 not conducting, CR1 not conducting.
b. Q1 conducting, CR1 not conducting.
c. Q1 conducting, CR1 conducting.

7. Notice that once again the UJT provides two very different types of outputs.

8. In the circuit on Template M, base 2 provides a ________________ waveform.

   a. square
   b. sine
   c. trigger
   d. sawtooth

9. In the circuit on Template M, the emitter provides a ______________ waveform.

   a. square
   b. sine
   c. trigger
   d. sawtooth

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MODULE 25

INFORMATION SHEET 25-I-1

REFERENCE:

A. Module 25 "Special Devices" Study Booklet (1 April 1977)
B. Student Handout #212, Page 212-31, Figure #1 (August 1981)
C. Instruction Manual, Function Generator NIDA Trainer Model 204

UNIJUNCTION OSCILLATOR (PC204-6)

The purpose of the unijunction oscillator printed circuit card is to form a ramp ( ) output signal. Ramp generation is a result of interaction between the unijunction transistor (UJT) Q2-6, C1-6, and the constant current source Q1-6. C1-6 is paralleled by C9 through C12 (located on the chassis) depending on FREQUENCY switch S2 position. When C1-6 is used in the text, understand that one of the FREQUENCY capacitors is in parallel with it.

Slow charging of the capacitor produces the leading edge of the ramp signal, while fast discharge action of the UJT produces the trailing edge of the ramp output signal. See Figure #1.


Figure #1

The charge path of C1-6 is from ground up through the capacitor, through Q1-6 and it's associated circuitry (Current Source), to Vcc. Since the front panel FREQUENCY CONTROL (R21A) is connected in series with the Q1-6 emitter, varying the FREQUENCY CONTROL will vary the current through the Constant Current Source. This will directly vary the charge time of C1-6, ie; more current causes the capacitor to charge faster, less current causes the capacitor to charge slower. This controls the frequency of the ramp output signal.

The reason for using a Current Source is to ensure that the capacitor (C1-6) is provided a constant current so that it will charge at a linear rate, plus producing a smooth linear ramp output. See Figure #2.


Figure #2

We will briefly review the operation of a UJT. All transistors need a certain bias level to operate. The UJT is no different. Base 2 of UJT is normally connected to some positive value. Base 1 is at some value of voltage less positive than that on Base 2. At different points between the base leads we would read different voltage levels. This sequential rise in voltage is called a VOLTAGE GRADIENT, and is linear between Base 1 and Base 2.

During manufacture the emitter is connected at some point between B1 and B2 so that it feels a certain percentage of the B1-B2 voltage, such as 70%, or 0.7. The actual emitter to Base 1 voltage at which the UJT conducts is therefore dependent on B1-B2 voltage. The E-B1 voltage required to saturate the E-B1 junction is the gradient voltage.

If we apply a voltage level to the emitter that is greater than the Voltage Gradient potential, the UJT will conduct heavily through the Base 1-emitter junction (saturate).

Once the UJT starts conducting, the voltage on the emitter will decrease to a low value which, at a point determined by the type of UJT and it's physical construction, will cause the UJT to stop conduction (cut-off) and act like an open circuit and no current will flow through the Base 1-emitter junction.

While observing the schematic in your Student Handout (reference B), follow the operation of the unijunction oscillator (Ramp Generator).

When power is applied to the unijunction oscillator, C1-6 will begin to charge through Q1-6. The capacitor will charge slowly, thus creating the leading edge of the ramp. Notice that the capacitor is connected directly to the emitter of the UJT (Q2-6). When the charge on the capacitor reaches the voltage level necessary to forward bias the UJT and cause it to conduct (greater than the potential of the Voltage Gradient where it is connected) the Base 1-emitter junction will conduct heavily and allow C1-6 to discharge through R3-6. Because of the very small value of R3-6 (47 ohms), the capacitor will discharge very rapidly, thus creating the trailing edge of the ramp. When the capacitor discharges, the UJT will stop conducting (cut-off), due to the decrease in the emitter voltage and the capacitor will once again begin to charge through Q1-6, thus beginning another ramp. This repeated charge and discharge action of the capacitor is what causes the unijunction oscillator to give us an output of the continuous ramps in the INTERNAL mode of operation.

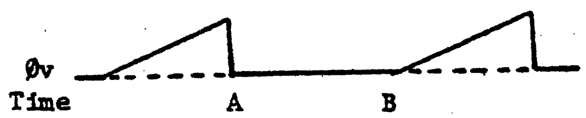
The purpose of the <u>F</u>ield <u>E</u>ffect <u>T</u>ransistor (Q3-6) is to couple the ramp output signal produced by C1-6, through PC204 output circuits to the ramp output amplifier of the Function Generator. Because of the FET's extremely high input impedance, it will not load the unijunction oscillator down, disrupting the linear charging action of the capacitor. In this way it is used to provide isolation between the unijunction oscillator and the ramp output amplifier.

<u>SILICON CONTROLLED RECTIFIER (SCR) CONTROL CIRCUIT (PC204-5)</u>

The purpose of the SCR Control circuit is to determine at what interval we will permit the unijunction oscillator to produce a ramp output signal, when using the EXTERNAL TRIGGER mode of operation. As you should remember from the UJT card

explanation, in the INTERNAL mode of operation, C1-6 will begin to charge and form another ramp immediately after it has discharged (completing the previous ramp) giving you an output of continuous ramps.

When we are in the EXTERNAL TRIGGER position, C1-6 will be held in a discharged state after completing a ramp, thus preventing an output of continuous ramps. The period of time between ramps will be determined by the external trigger input signal. See the example given in Figure #3 below.




NOTE: From Time A to Time B, C1-6 is being held in a discharged state due to the action of the SCR Control circuit.

Figure #3

We will briefly review the operation of a Silicone Controlled Rectifier. The SCR is very similar to the diode rectifier. A diode, as you recall has an ANODE and CATHODE. The SCR has an ANODE and CATHODE with the addition of a third element called a GATE. The gate lead is attached to the cathode of the SCR.

Another similarity that exists between the diode and the SCR is that both must be forward biased in order to conduct. Also current flows against the arrow.

Unlike the diode the SCR will not conduct with just forward bias across it. The SCR must have a positive signal applied to the gate at the time it is forward biased to conduct. Even with forward bias across it, with no positive signal on the gate lead it is essentially an open circuit and will not pass current.

The gate works like a "turn on" switch during the time the SCR is forward biased. Once the SCR is conducting (turned on), the gate no longer has any control. In other words the gate can not turn the SCR off.

The only way to stop the SCR from conducting once it has been "turned on", is to reduce the current flow through the SCR below the minimum HOLDING current required to sustain conduction. This is normally accomplished by one of the following methods:

A. REMOVE THE FORWARD BIAS FROM THE SCR.
B. REVERSE BIAS THE SCR.
C. OPEN THE CURRENT PATH OF THE SCR.
**D. STARVE THE SCR OF CURRENT UNTIL IT'S CURRENT LEVEL FALLS BELOW THE REQUIRED "HOLDING" CURRENT.

Therefore, to "turn on" an SCR you must have it forward biased and a positive signal applied to it's gate at the same time. To "turn off" an SCR you must use one of the methods described above.

In the SCR Control circuit used in the NIDA 204 Function Generator we will use method "D" for SCR1-5 and method "A" for SCR2-5.

**The Instruction Manual, Function Generator NIDA Trainer Model 204, Page 2-9 gives a detailed description of method "D" as it applies to PC204-5.

EXTERNAL TRIGGER MODE OPERATION

Since not only does the SCR Control Circuit control the Unijunction Oscillator, but the Unijunction Oscillator controls the SCR Control Circuit, it is impossible to explain the operation of the SCR Control Circuit alone. So we will discuss how the SCR and UJT cards work together to produce the ramp output signal when in the EXTERNAL TRIGGER mode of operation.

Looking at the schematic in the Student Handout (reference B), you can see that with the Trigger Switch (S5) in the EXTERNAL position, Pin #7 of the SCR card is now connected through the switch to Pin #12 of the UJT card. This section places the Unijunction Oscillator under the control of the SCR Control circuit.

In the EXTERNAL TRIGGER mode, a sine wave input signal is applied to the input jack (J17) from an external source (signal generator). This sine wave is sent through a SQUARING AMPLIFIER, converted to a pulse wave, and then fed to Pin #5 of the SCR card. The frequency of this input signal will ultimately determine the output frequency of the external ramps.

When power is applied to the Function Generator, C1-6 will begin to charge through Q1-6. When the charge on the capacitor reaches a sufficient voltage level, Q2-6 will conduct heavily Base 1-emitter and C1-6 will discharge through R3-6, thus creating a ramp output signal from the unijunction oscillator.

The discharge current through R3-6 will produce a positive pulse (spike) on Pin #3 of the UJT card. This pulse is felt at Pin #10 of the SCR card and coupled through CR3-5 and R9-5 to the gate of SCR2-5. This positive pulse will gate SCR2-5 into conduction.

The primary current path for SCR2-5 is from ground, through SCR2-5 cathode to anode, through R8-5 and R7-5 to the power source (Vcc). Due to the size of resistor R7-5 (4700 ohms) most of the applied voltage will be dropped across it leaving a low voltage on the cathode of CR2-5, forward biasing the diode. The low voltage on the cathode is then felt on Pin #7 of the SCR card, through the Trigger Switch (S5), and in Pin #12 of the UJT card. This low voltage is then felt at the top of C1-6 and will prevent it from charging to full potential, thus not allowing the UJT (Q2-6) to turn on and no ramp output signal will be generated.

At the same time the above action was taking place, SCR2-5 has a secondary current path through C2-5 and R6-5 to Vcc. This current will cause C2-5 to charge.

The SCR/UJT circuits will remain in this state until a negative pulse is applied to Pin #5 of the SCR card.

When the negative pulse is applied to Pin #5 it is inverted by Q1-5 and the resulting positive pulse is applied to the gate of SCR 1-5. When the pulse has a high enough voltage and is applied to the gate of SCR 1-5, SCR 1-5 will conduct and the voltage potential at the anode of SCR 1-5 will decrease by a large amount. Capacitor C2-5 will couple the decrease in potential to the anode of SCR 2-5. Since the potential on the anode of SCR 2-5 was low already (SCR 2-5 conducting), the decrease in potential will cause the total potential on the anode of SCR 2-5 to go below 0 volts, thus causing SCR 2-5 to cutoff. When SCR 2-5 cuts off its cathode-anode resistance and the resistance at cathode of CR 2-5 will be very high again. Since R6-5 is high resistance, due to circuit design, the current through SCR 1-5 cathode-anode will be low, but enough to keep SCR 1-5 from cutoff.

Remember, a characteristic of an SCR is that a certain amount of current flow through the cathode-anode is required to maintain conduction. With SCR 1-5 now conducting and SCR 2-5 cutoff, C 2-5 is able to discharge through the low resistance of forward biased CR 1-5 (cathode to anode) and the conducting SCR 1-5 (cathode to anode). The added current from C 2-5 discharging through SCR 1-5 will keep SCR 1-5 in conduction until C 2-5 has discharged. Then SCR 1-5 will cutoff.

Now let us look at the operation of the UJT again. When SCR 2-5 was cutoff, there was no current flow through R8-5 and R7-5 thus no voltage drop across R7-5 and R8-5, placing Vcc (a high voltage) on the cathode of CR2-5 and the anode of SCR2-5. With Vcc on it's cathode CR2-5 is reverse biased. With CR2-5 reverse biased we remove the low potential from Pin #7 of the SCR card; Pin #12 card of UJT card and from the top of C1-6. This will allow C1-6 to begin charging to it's normal value and the unijunction oscillator will now be allowed to produce another ramp output signal. As soon as the UJT's emitter reaches a sufficient level of voltage, the UJT will conduct allowing C1-6 to discharge, thus sending another pulse to the gate of SCR2-5 causing it to conduct again, starting the process over.

It is important for you to understand the operation of the circuits described here <u>PRIOR</u> to attempting to troubleshoot these circuits in the Performance Test.

# JOB PROGRAM FOR LESSON II PART 3

## UJT Ramp Generator and SCR Control Circuit

### EQUIPMENT AND MATERIALS

1. NIDA 204 Function Generator
2. Oscilloscope
3. Signal Generator
4. BNC-BNC Cables (2)
5. 1X Probe (2)
6. Jumper Wire with Alligator Clip Ends (1)
7. Prefaulted cards PC 204-5 and PC 204-6 (Obtain in Step 26)

### PROCEDURE

IMPORTANT: The NIDA 204 INSTRUCTION MANUAL is a "must" in learning to troubleshoot the NIDA 204 Function Generator. If you haven't already done so, get the Instruction Manual and read it! Instruction or "Tech" Manuals are an invaluable asset to the technician. Study thoroughly the following pages in the NIDA 204 Instruction Manual. (You might be surprised at how much easier your Job Programs and PT's are).

Pages 2-20 through 2-23
pages 2-27 through 2-29
pages 2-30 through 2-32 (Table 2-1; Circuit Interface)
pages 3-2 through 3-5 (Table 3-1; Faulty Circuit Location Guide)
pages 3-6 through 3-12 (Troubleshooting Guide)

1. Energize the oscilloscope and set it up for CHANNEL 1 and INTERNAL MODE operation. Using a BNC-BNC cable connect the NIDA 204 Function Generator OUTPUT jack to CHANNEL 1 of the oscilloscope. Energize the signal generator to warm up for later use.

2. Set up the NIDA 204 Function Generator front panel controls as follows:

   a. TRIGGER to INTERNAL
   b. FREQUENCY SWITCH to 1000 Hz
   c. FREQUENCY DIAL to 3 (may vary 1.5 - 3)
   d. OUTPUT LEVEL fully CLOCKWISE
   e. SYMMETRY fully CLOCKWISE
   f. FUNCTION SWITCH to (Ramp)

3. Remove the top cover of the NIDA 204 and ensure all eight PC cards are in place.

4. Plug in and energize the Function Generator.

5. Observe the output waveform from the Function Generator. The output should be a ramp (sawtooth) voltage with a smooth (straight line) rise. The basic UJT oscillator in your study booklet had an "integrated" (curved line) output. The UJT oscillator in the NIDA 204 has some additional circuits that make the output linear.

Refer to Figure 1 in this job program and locate PC 204-6. This is a schematic of the UJT Oscillator - Ramp Generator.

NOTE: Transistor Q1-6 and its associated circuitry (R2-6, CR1-6, CR2-6, CR3-6, and R1-6) comprise a "Current Regulator". This current regulator will maintain current through the UJT emitter capacitors at a constant value resulting in a linear "Ramp" output.

6. Transistor Q3-6 is another device you are probably not familiar with. It is called a "Field Effect Transistor", or, to shorten the name a bit, FET. This FET and its associated components (R6-6 and R7-6) make up an amplifier circuit. An FET is used as an amplifier because it has a high input impedance and will not load the UJT circuit. If a regular transistor were used in place of the FET, the output would be distorted.

7. Refer to Figure 1 and answer the following questions:

(1) The FREQUENCY SWITCH (S2) will change the (capacitance/resistance) of the UJT oscillator.

(2) With the FREQUENCY SWITCH (S2) in the "1000 Hz" position, capacitor (C9/C10/C11/C12) is in (series/parallel) with C1-6.

8. The FREQUENCY dial (R21A) sets the conduction level of the current regulator. If the regulated current increases, the capacitors in the emitter circuit of the UJT will charge more quickly and increase the output frequency.

(1) The FREQUENCY potentiometer (R21A) is in (series/parallel) with R2-6.

Now that we have checked the operation of the UJT circuit, let's take a look at the SCR control circuit operation. (Refer to Figure 1 and locate PC 204-5 SCR control Circuit).

9. Deenergize and unplug the NIDA 204 Function Generator.

10. Remove the Unijunction Oscillator printed circuit card PC204-6.

11. Connect a 1X probe to the oscilloscope's channel "2" input and set up the oscilloscope for channel "2", INTERNAL TRIGGER mode.

12. Plug in and energize the NIDA 204 Function Generator.

13. Using the oscilloscope, measure and record the DC voltages at the anode and cathode of SCR2-5.

(1) Anode: ____________ VDC
(2) Cathode: ____________ VDC
(3) Is SCR 2-5 conducting? (YES/NO)

HINT: Whenever the difference in potential between the anode and cathode of an SCR exceeds 0.6 volts, the SCR is not conducting.

(4) Is SCR 2-5 forward biased?

(5) What else is required to turn on SCR 2-5?

a. Reverse bias SCR 2-5.
b. Forward bias SCR 2-5.
c. Apply a positive signal to SCR 2-5's gate lead.
d. Apply a negative signal to SCR 2-5's gate lead.

14. Now we are going to turn SCR 2-5 on by applying a positive signal to the gate lead: de-energize NIDA 204 and connect one lead of a jumper to PC 204-7, pin 3, and leave the other end free. Energize and momentarily touch the free end to PC 204-5, pin 10.

(1) Is SCR 2-5 conducting? (YES/NO)

15. Place the lX probe at the SCR 1-5 gate lead. Carefully observe the oscilloscope trace for a "pulse" while rapidly pressing and releasing the TRIGGER SWITCH (S5).

NOTE: The TRIGGER switch will be in the "MAN" (manual) position when depressed and is spring loaded to return to the "EXT" (external) position when released. Use the .5v/div position on the oscilloscope channel "2".

(1) The signal applied to the gate lead of SCR1-5 when the TRIGGER switch is depressed is a

a. positive going trigger.
b. negative-going trigger.

NOTE: A section of the TRIGGER switch, not shown on Figure 1, applies a negative signal to the base of transistor Q1. The signal is differentiated, inverted and applied to the gate lead of SCR 1-5. (Refer to Figure 1.) Use the .5 v/div position on the oscilloscope channel "2". Shift to AC input mode.

16. Move the lX probe to the anode of SCR 1-5. Carefully observe the oscilloscope trace while depressing and releasing the TRIGGER switch (S5).

(1) When the TRIGGER switch (S5) is placed in the "MAN" (manual) position SCR 1-5

a. "turns off" momentarily then "turns on" again.
b. "turns on" momentarily then "turns off"

NOTE: When SCR 1-5 conducts, capacitor C2-5 will discharge through CR1-5 and SCR1-5. Resistor R6-5 in the anode circuit of SCR1-5 is a high value resistor. There is insufficient current thorugh R6-5 (holding current) to maintain SCR1-5 in conduction. SCR1-5 will "shut off" when capacitor C2-5 is discharged. The discharge path for C2-5 is through the forward biased CR1-5 and SCR1-5.

17. Move the 1X probe to the anode of SCR 2-5.

(1) Is SCR 2-5 conducting? (<u>YES/NO</u>)

18. Turn on SCR 2-5. (Momentarily connect a jumper between PC 204-7, pin 3, and PC 204-5, pin 10.)

19. While observing the oscilloscope trace, place the TRIGGER switch (S5) to "MAN". This action causes SCR1-5 to conduct, discharges C2-5 and drives the anode of SCR2-5 negative; thereby shutting SCR2-5 "Off".

We will now see how the SCR Control Circuit and the UJT Oscillator-Ramp Generator work together.

20. Deenergize the NIDA 204 Function Generator and insert the UJT Oscillator-Ramp Generator printed circuit card, PC204-6.

21. Ensure the NIDA 204 Function Generator is set up as follows:

a. FREQUENCY switch (S2) to "1000 Hz".
b. FREQUENCY dial (R21A) to "3". (vary 1.5 - 3)
c. TRIGGER switch (S5) to "INT".
d. INPUT SENSITIVITY control Fully clockwise.
e. TRIGGER LEVEL fully counter clockwise.
f. OUTPUT LEVEL fully clockwise.
g. FUNCTION switch to " ".

22. Using a BNC-BNC cable, connect the Audio Output Jack from the Signal Generator to the input of the NIDA 204. Set up the Signal Generator as follows:

(1) AN/URM-25

a. METER READS switch to "400 Hz."
b. AUDIO OUTPUT to read 5 on the microvolt scale.

(2) WAVETEK 186

a. 400 Hz sine wave, 4v pk-pk, no offset
b. The 50Ω output is used when using the Wavetek 186.

23. Energize the NIDA 204. Set up the oscilloscope for channel "1", connect a 1X probe to pin 9 of PC-204-6 and observe the waveform on the oscilloscope, then replace the TRIGGER switch (S5) on the NIDA 204 to "EXT".

(1) The number of ramps displayed on the oscilloscope (increased/decreased/remained the same).

NOTE: The number of ramps displayed decreased because placing the TRIGGER switch (S5) to "EXT." allowed the SCR control circuit to control the UJT Oscillator - Ramp Generator. (Figure 1 shows the interconnection between the UJT and SCR circuits you have just studied).

24. Place the oscilloscope's channel "2" probe on base 1 of the UJT (Q2-6). Look closely for a positive trigger.

NOTE: Set up the oscilloscope as follows to better observe the trigger:

(a) DISPLAY MODE switch to "chop".
(b) TRIGGER SOURCE to "Internal".
(c) TIME/DIV to ".5 millisecond/div."
(d) CHANNEL "1" VOLTS/DIV to "5 volts/div."
(e) CHANNEL "2" VOLTS/DIV to "5 volts/div."

(1) The positive trigger from Q2-6 base 1 will cause SCR 2-5 to (conduct/turn off).

NOTE: When the TRIGGER switch (S5) is in the "external" position and SCR2-5 conducts, the UJT circuit cannot generate another ramp.

25. Place the channel "2" 1X probe on the gate lead of SCR 1-5.

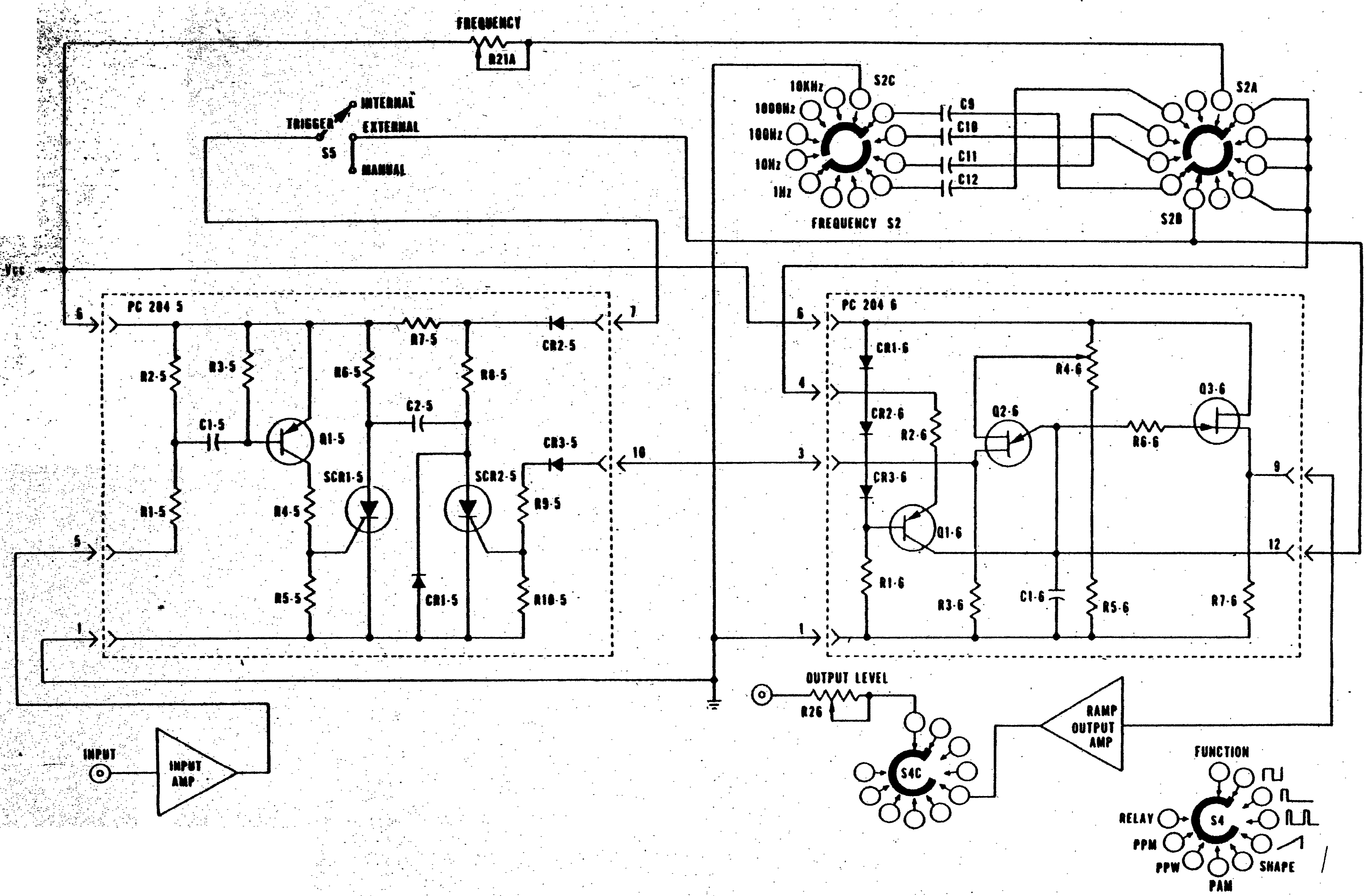
This signal originating from the signal generator (external input) will turn SCR1-5 (on/off).

NOTE: When SCR1-5 turns "on", SCR2-5 turns "off" and another ramp will be generated by the UJT circuit. Therefore, using an SCR control circuit allows us to determine when a ramp will ge generated.

26. Now that you have observed the normal operation of a SCR control and UJT ramp generator circuits, insert the prefaulted SCR control card and troubleshoot it to its faulty component. After you have located the faulty component, insert the operational SCR control card and the prefaulted UJT ramp generator card and troubleshoot it.

27. Check with your learning center instructor to see if your diagnosis of the faults was correct.

CHECK YOUR RESPONSES TO THIS JOB PROGRAM WITH THE ANSWER SHEET. IF YOUR RESPONSES AGREE WITH THE ANSWER SHEET, YOU MAY TAKE THE LESSON PROGRESS CHECK. IF YOUR RESPONSES DO NOT AGREE OF IF YOU FEEL YOU HAVE FAILED TO UNDERSTAND ALL, OR MOST OF THIS JOB PROGRAM, REVIEW THE PROCEDURES OF THIS JOB PROGRAM, ANOTHER WRITTEN MEDIUM OF INSTRUCTION, AUDIO/VISUAL MATERIALS OR CONSULTATION WITH LEARNING CENTER INSTRUCTOR UNTIL YOUR RESPONSES DO AGREE.



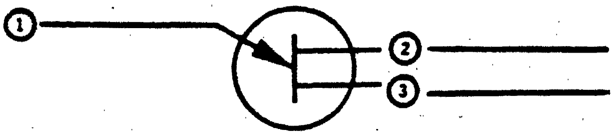

## RAMP MODE

FIGURE 1

PROGRESS CHECK
LESSON II

## Unijunction Transistor Theory

1. Label the leads on the schematic symbol of the UJT.



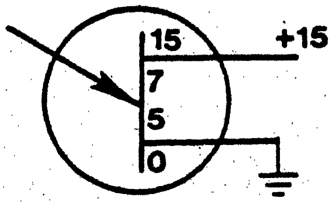

2. The material between the bases of the UJT acts as a ________.

3. The emitter of the UJT must be ______________ in respect to the ____________________ in order for the UJT to conduct.

4. The sequential rise in potential between Base 1 and Base 2 is called a/an ____________________.

5. The small amount of current flow in a reverse biased UJT is called ________________.

6. What is the conduction point of the UJT shown below? ________



7. What does the waveform at TP "A" look like in the circuit shown below?

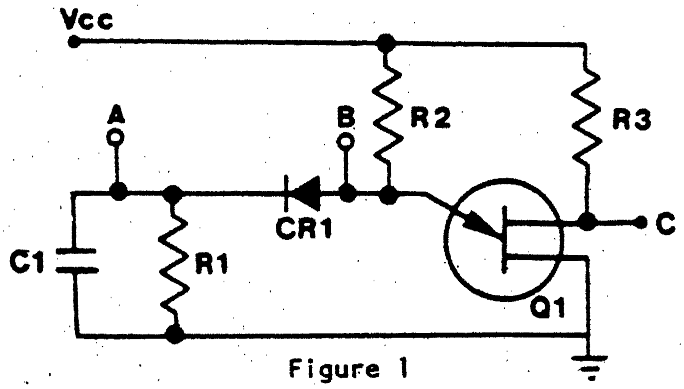
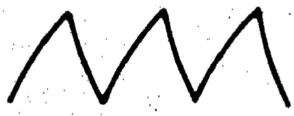


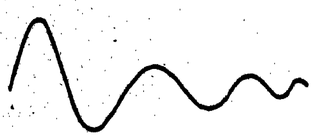

Figure 1

a.

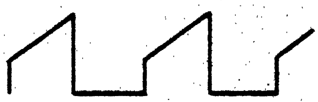


c.

b.



d.



8. The shape of the waveform at TP "C" in Figure 1 is determined by the

a. on/off state of Q1.
b. on/off state of CR1.
c. time constant of C1, R2.
d. time constant of CR1, R1.

9. The waveform at TP "A" in the circuit shown in Figure 2 looks like:

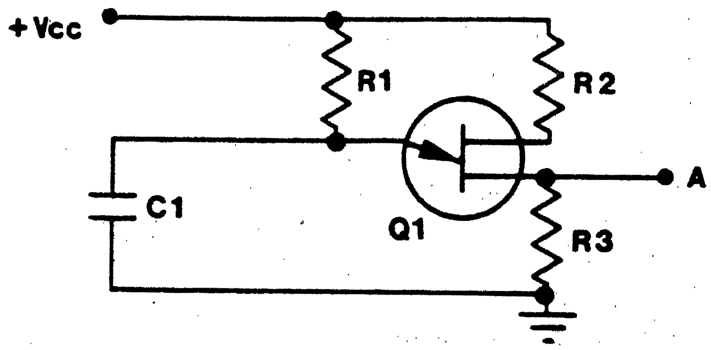
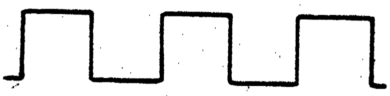
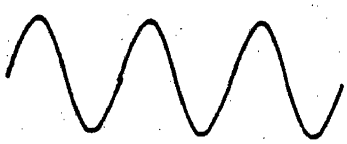
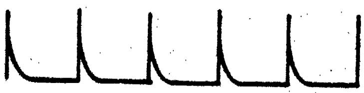



Figure 2

a. 

b. 

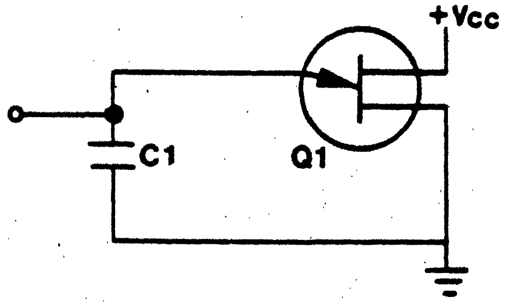
c. 

d. 

10. The frequency of the waveform at TP "A" in Figure 2 is determined by C1 and

a. Q1.
b. R1.
c. R2.
d. R3.

11. In the circuit shown in Figure 3 C1 charges through:




a. Q1's B1 - B2 junction.
b. Q1's E - B2 junction.
c. Q1's E - B1 junction.
d. ground.

12. The current that charges C1 is called ____________________.

CHECK YOUR ANSWERS TO THIS PROGRESS CHECK WITH THE ANSWERS IN THE BACK OF YOUR STUDENT GUIDE. IF YOU FEEL THAT YOU HAVE FAILED TO UNDERSTAND ANY PART OF THIS LESSON YOU SHOULD CONSULT YOUR LEARNING CENTER INSTRUCTOR FOR ASSISTANCE AND REMEDIATION. IF YOU ANSWERED ALL QUESTIONS IN THE PROGRESS CHECK CORRECTLY, CONSULT YOUR LCI FOR ASSIGNMENT TO THE MODULE TEST.

A.S. (J.P.) Twenty Five-I-1

ANSWER SHEET
FOR
JOB PROGRAM
LESSON I
PART 1

## Silicon Controlled Rectifier DC Control

2. no
4. c. There is no gate voltage applied.
5. b. The SCR will conduct.
7. d. Applied positive voltage to the gate lead.
8. no
10. c. Remove shorting straps.

A.S. (J.P.) Twenty Five-I-2

ANSWER SHEET
FOR
JOB PROGRAM
LESSON I
PART 2

## Silicon Controlled Rectifier AC Control

3. half wave
4. diode
6. conducts
9. more
10. increased
11. a. SCR conduction begins at the time the gate signal reaches the "Turn on" voltage level.

A.S. (Progress Check) Twenty Five-I

ANSWER SHEET
FOR
PROGRESS CHECK
LESSON I

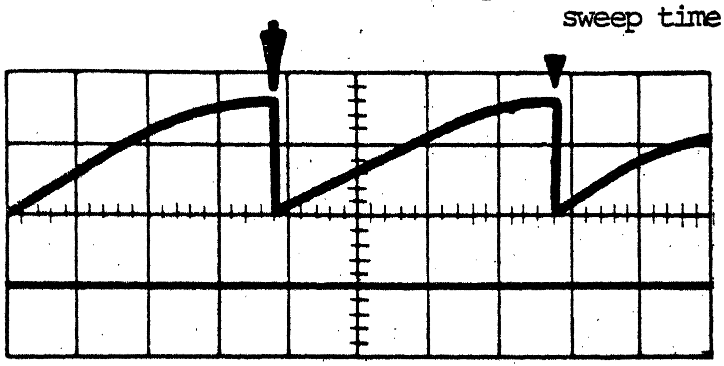
## Silicon Control Rectifier Theory

| QUESTION NO. | CORRECT ANSWER | QUESTION NO. | CORRECT ANSWER |
|---|---|---|---|
| 1. | b. | 7. | b. |
| 2. | diode | 8. | d. |
| 3. | gate, anode, cathode (any order) | 9. | a. |
| 4. | c. | 10. | d. |
| 5. | a. | 11. | d. |
| | a. | | |

ANSWER SHEET
FOR
JOB PROGRAM
LESSON II
PART 1

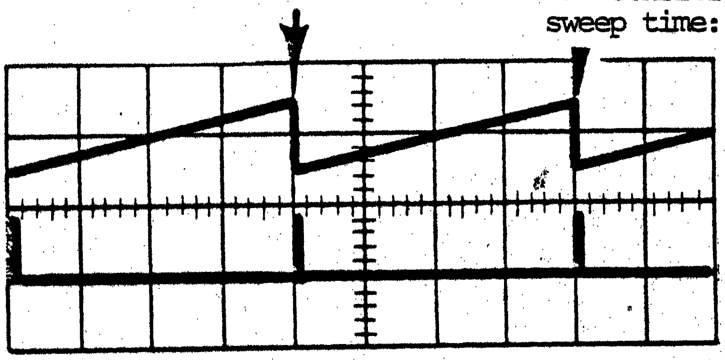
U.J.T. Sawtooth Trigger Generator

3. waveform taken with oscilloscope: "A" sensitivity .5 volts/cm
sweep time: 1 milliseconds/cm



4. a. sawtooth
   b. +.75 volts peak to peak
   c. (The arrows on the above waveform indicate the U.J.T. conduction points.)

5. waveform taken with oscilloscope: "A" sensitivity: .5 volts/cm
"B" sensitivity: 2 volts/cm
sweep time: 2 milliseconds/cm



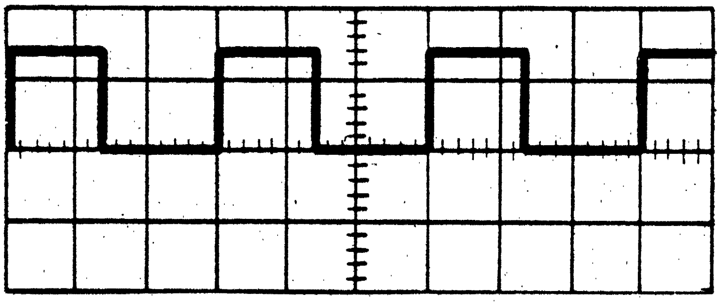
6. a. trigger
   b. +2 volts p-p
   c. most positive

7. a. sawtooth
   b. trigger

ANSWER SHEET
FOR
JOB PROGRAM
LESSON II
PART 2

U.J.T. Multivibrator

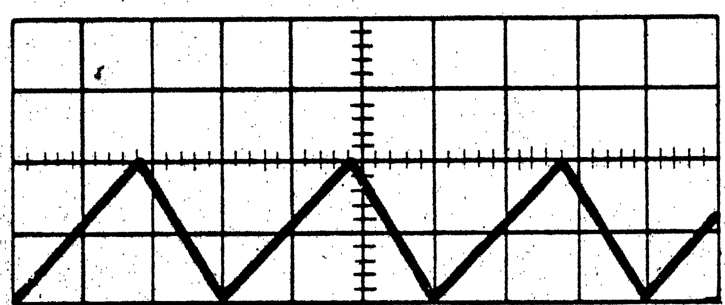
3. a. waveform taken with oscilloscope: "A" sensitivity .5 volts/cm
sweep time: 2 milliseconds/cm



b. square wave

c. .7 volts peak to peak

4. a. waveform taken with oscilloscope: "B" sensitivity .5 volts/cm
sweep time: 2 milliseconds/cm

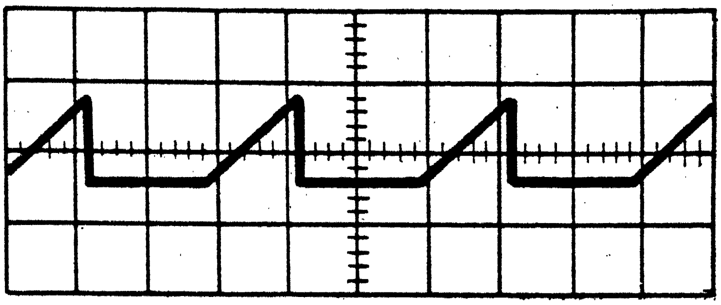


b. sawtooth

c. .8 volts peak to peak

d. +.8 volts

5. a. Waveform taken with oscilloscope: "B" sensitivity .5 volts/cm
Sweep time: 2 milliseconds/cm



b. Yes

c. Because of the halfwave rectification of diode CR1 (or words to that effect.)

6. b.

8. a.

9. d.



ANSWER SHEET
FOR
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LESSON II
PART 3

7. (1) capacitance
(2) C12; parallel

8. (1) series

13. (1) 22VDC (± 10%)
(2) 0VDC
(3) No
(4) Yes
(5) c.

14. (1) Yes

15. (1) a.

16. (1) b.

17. (1) No

23. (1) decreased

24. (1) conduct

25. (1) on

ANSWER SHEET
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PROGRESS CHECK
LESSON II

Unijunction Transistor Theory

| QUESTION NO. | CORRECT ANSWER |
|---|---|
| 1. | a. emitter<br>b. base 2<br>c. base 1 |
| 2. | resistor |
| 3. | positive, base 1 (in that order) |
| 4. | voltage gradient |
| 5. | reverse current |
| 6. | +5 to +5 1/2v |
| 7. | a. |
| 8. | a. |
| 9. | d. |
| 10. | b. |
| 11. | b. |
| 12. | reverse current |